# Carbon, Climate, and the GINF Ratio

By Charles N. Standing, PhD, Dec.1, 2015

This opinion piece is a paper which is about climate change, energy finiteness, and world population reality. It is written for a general reading audience and, as such, contains many statements which would in no way constitute news for a person who is an expert in any one of these disciplines. At the same time, however, it brings these three areas together in several new ways, the purpose of which is to find a new path by which the general reader can judge the action needed for the future.

The letters GINF stand for Giant-Impact Non-Fungibles and the words "The GINF Ratio" refer to the sum of these "GINF's" divided by total world human population. These are terms which I have chosen to express what is hopefully at least part of a new way to find a path through the current maze which the world and mankind is facing.

The term Giant-Impact Non-Fungibles might need a few words of explanation. "Fungible" can potentially have quite a few meanings, albeit all of them are closely related. In this paper it means "able to be substituted for, in a completely meaningful way, if we were ever to run out of it." The word "Non-Fungible", therefore, is the reverse of this and means that the thing in question can <u>not</u> be substituted for, at least not in a way which is truly consequential. "Giant-Impact", of course, means that we are limiting ourselves to the discussion of things which have an extremely large significance for human beings, the world in general, and its climate. Indeed there are three Giant-Impact Non-Fungibles in this paper: crude oil, natural gas, and coal.

A major thesis of this piece is that what mankind is today and what mankind and its world might hope to be in the future are inextricably entwined with a key date in modern history, the year 1859, the "official" year of the modern-day discovery of crude oil.

Another major thesis is that crude oil, and its close associate natural gas, are in no way simply another very important source of energy. They are vastly more than this. They are tremendously unique in (a) their very high Btu density, (b) their portability and flowability, and (c) the sheer overwhelming total Btu's which they represented at the time of their modern-day discovery. Some of these same things can also be said for coal, of course, but of the three GINF's, coal is currently the most controversial and also is the most likely to be least used.

A third major hypothesis here is the "Non-Fungible" nature of crude oil, natural gas, and coal, a point which I will state here and prove later. Simply put, when we "run out of " resources such as these three, it is not going to be a simple question of accelerating the transition to wind and solar, or anything else for that matter. The reader will see later in this paper that (a) there will never be enough Btu's from these technologies to replace these fossil fuels, and (b) if somehow there <u>could</u> be, this massive build-out would require cheap and plentiful "seed energy" which could only come from the very fossil fuels which, now, we will no longer possess.

Complicating these latter points, of course, is the whole question of whether or not we should indeed even go out to the point of "running out" of the GINF's. Here I am speaking of the concept of "Stranded Assets" and the arguments which are made that a large percentage of the remaining fossil fuel reserves need to be left in the ground in order to mitigate further man-made climate change damage. I am not a climate change denier, but just as we have the concept of "Stranded Assets", so also I would introduce the concept of "Stranded Asset Users", meaning that if we are going to have both a large human population and a large average energy usage per person, then the pathways towards an end-point that gives us all of our desired results become very limited in number. We certainly all want no further climate change if we can get it, and we all want a comfortable lifestyle for our children and our grandchildren if we can secure that also, but the obtaining of all these things simultaneously in the context of a continued large human population is not extremely likely as we are about to see.

We now need to look at what has happened to the GINF Ratio in mankind's march from 1859 to today (while at the same time acknowledging that one of the GINF's, coal, was being used well before 1859), because the GINF ratio is not only a measure of per capita wealth of man, but I would submit that it is by far the most critical.

Going back to paragraph two of this paper, the GINF Ratio may be written in equation form as follows:

(1). G.R. (GINF Ratio) = Sum of total Giant-Impact Non-Fungibles ÷World Population.

In the same way as equation (1), we would have equations (2) and (3) for the years 1859 and 2015, respectively:

(2). G.R. 1859 = Sum of GINF's in 1859 ÷ World Population 1859

(3). G.R. 2015 = Sum of GINF's in 2015 ÷World Population 2015.

The calculations are straightforward. World human population in 1859 was about 1.3 billion and in 2015 is/was about 7.3 billion. The sum of the GINF's in 2015 is about 0.60 of what it was in 1859, using a Btu-weighted average of crude, gas, and coal, and also using reasonable assumptions regarding what remaining quantities which are in the earth yet today can be reasonably assumed to be truly extractable given technical, financial, and environmental limitations. Indeed the number 0.60 would be less than this if the concept of "Stranded Assets" is in fact applied in any significant way, and higher than this if one were able to count the best-case potential for "tight oil" and other non-conventional oil and gas plays.

Staying with the 0.60 (and 1.00 for 1859) for the moment, we have G.R. 1859 = 1.00 ÷ (1.3 x $10^9$) = 0.77 x $10^{-9}$ and we have G.R. 2015 = 0.60 ÷ (7.3 x $10^9$) = 0.082 x $10^{-9}$.

This then gives us our comparison of where we are today using this measure versus where we were in 1859. This comparison is $\frac{0.77 \, x \, 10^{-9}}{0.082 \, x \, 10^{-9}}$ = 9.4. That is, using this metric, mankind is about 9 times less wealthy per capita today than he was in 1859. And, once again, I am fully acknowledging the fact that climate change arguments could completely negate the statement "9

times less wealthy", but it is also true that this opinion piece is attempting to synthesize the three disparate areas of climate change, energy finiteness, and world population reality.

So, for the moment then, it could be argued that we are about 9 times less wealthy today than in 1859 using this particular ratio.

Now we all know that there are also many other ratios which could be cited here as well, many of them vastly less unfavorable to humankind and even, I am sure, quite favorable. For example, one could argue that the total useful knowledge possessed by man in 2015 is/was perhaps ten times or even one hundred times what it was in 1859. If so, we could then postulate a "Wealth by Inventiveness Ratio" in which a number such as this ten times would easily overcome the increase in population, and a number like this one hundred times would easily overhelm it. And this may very well be true! But here is something that is also true: Wealth by inventiveness, or total useful knowledge possessed by mankind, or pretty much anything else for that matter, is very limited in what it can actually physically create without the basic Btu's behind it to power it to implementation.

These are the opinions of this writer, and so also are they the opinions of this writer the summary points which I have written in Table 1.

In Table 1, I have attempted to summarize and also synthesize the three interrelated phenomena which will define the immediate and long-term future of mankind's current (average) lifestyle and also the medium - and long –term future of non-human life on this earth.

The various summary points in this table paint a picture which in my view shows that we are boxed into a corner from which there are very few degrees of freedom and/or pathways by which we can find total resolution.

The first item in Table 1, item A., is Climate Change, and we are all well aware that there is a large pro/con reality in existence regarding whether or not current climate change is human-produced by way of the burning of fossil fuels. While I personally believe that there are compelling points to the contrary, I nevertheless feel that there are points even more compelling on the pro side, and I would state that currently seen and measured climate change is probably human-caused to the extent of 50% or more, the balance, if any, being from natural fluctuations such as solar irradiance.

In column 2 for item A, I have written the point (or "solution") which many observers have brought forward that the resolution to current climate change is simply to stop using the fossil fuels that in fact are still in existence <u>and</u> extractable. This is sometimes referred to as the concept of "Stranded Assets", that we should "strand" or not use these particular energy assets.

# Table 1

Summary statements for the three related issues of climate change, energy finiteness, and world human population.

| **Problem** | **Possible concepts to mitigate this problem** (a) | **Negatives associated with the points in column two** (a) | **Positives associated with the points in column two** |
|---|---|---|---|
| A. Climate Change | 1. Simply leave a large percent of GINF's (fossil fuels) in the ground, unused, as "Stranded Assets" | 1. By creating "Stranded assets" we are creating "Stranded asset users" since mankind is now accustomed to about 73 quads of energy per year per billion humans. | 1. Climate change might theoretically be resolved if this were done. |
| B. Energy Finiteness | 1. Build out the renewables to the extent of 500 or 1000 quads per year. | 1. Renewables are currently only about 72 quads total per year, and a ten-fold increase would require fossil fuel "seed energy". | 1. There is a small chance that the statement in column three could prove to be wrong, albeit extremely small. |
| C. Human Population at between 9 and 11 Billion. | 1. Greatly decrease the quads per billion of population that we are currently using. | 1. Even if we crest at only 9 billion and cut energy per billion by 20%, we still would need 500 to 1000 quads per year because, without the fossils, we are "all electric". | 1. Decrease quads per billion humans by far more than 20%, unfortunately very unrealistic due to "increased desire for upward mobility" of less advanced peoples. |
| | 2. Decrease human population and allow this number to stabilize at 4 billion or less. | 2. This would require an end to the decades-old "gag rule" and a significant decrease in our "organic economic growth" | 2. This is most probably the only path to resolving both problems A. and B, problems which absolutely must be solved. |

*a: A quad is a quadrillion (*$10^{15}$*) Btu's.*

I am against this concept for several reasons, some of which will not be clear until we have fully discussed items B. and C. of Table 1. For now, however, I will emphasize quite simply what I have written in column 3 for climate change, namely that if we are going to resort to stranded assets, then we are automatically and simultaneously creating what I have chosen to call "Stranded Asset Users", by which I am referring to the facts that (a) we do indeed have about 7.3 billion people on earth, (b) these people are currently using about 73 quads of energy per billion persons per year, (c) the overwhelming majority of these quads are currently coming from fossil fuels, and (d) these fossil fuels are in fact GINF's; that is, they are not only Giant-Impact energy sources, but they are also Non-Fungible, being either non-replaceable or at least only replaceable in a highly limited and restricted sense.

My own suggestions to arrest human-caused climate change will become completely clear as we finish the final points of this opinion piece.

The second area in Table 1, item B., is Energy Finiteness. In my opinion, this is an area that is not well understood in spite of the literally tens of millions of words which have been written on this subject over the past 45 years. In order to understand this once and for all, we need to introduce a very simple second table, Table 2, below.

**Table 2**

Worldwide Quads and Their Sources in 2014 *(a)*

| Energy Source or Type | Approximate Quads used or generated in 2014 *(b)* |
|---|---|
| 1. Crude oil, all types: | 180 |
| 2. Natural gas: | 125 |
| 3. Coal: | 125 |
| 4. Nuclear Fission : | 30 |
| 5. Hydroelectric: | 12 |
| 6. Biomass: | 48 |
| 7. Biofuels: | 2 |
| 8. Geothermal: | 2 |
| 9. Wind, onshore & offshore: | 5 |
| 10. Solar (residential, Non-residential, and utility) | 3 |
| | 532 |

*a: Some smaller sources do not appear in this table; example: Tidal, which was at well under one quad in 2014.*
*b: Certain numbers require various conversion factors such as 0.293 watt-hours/Btu, etc.*

Here I have listed the ten categories of energy sources by number of quads worldwide, used in the year 2014. The numbers are approximate and are condensed from various sources and data sets in the literature and the Internet, including the Energy Information Administration (eia.gov), the U.S. Geological Survey (usgs.gov) and many others.

As can be seen, the total number of quads is 532; that is, human activity consumed about 532 quadrillion Btu's of energy in 2014, or about 73 quads per billion of human population.

The sum of the top three lines in Table 2, the numbers for crude oil plus gas plus coal, is 430 quads, about 81% of the 532 total. These are the "GINF's", and by many very reasonable reckonings will be gone, or nearly so, by about the year 2095 <u>or</u>, as an outside number, 2095 plus <u>another</u> increment of 75 or 80 years. The most important thing to remember is that the latter possibility is <u>not</u> superior to the former; it is worse. It is worse because added time-frame complacency would likely allow world human population to crest at an even higher high-water mark than it otherwise would have, further exacerbating the overall picture for the triumvirate of interconnected superproblems which we are treating here.

Items 4. through 10. in Table 2 sum to a total of about 102 quads, the other roughly 19%.

There are people who believe that when the fossil fuel sources are gone (in a practical sense), that "something will come along", and that mankind will not only continue to have sufficient energy but that it will also be better energy because it will be less environmentally impactful. This writer would be the first to say how much he wishes that this could in fact be true.

Table 2, however, is surprisingly "graphic" and is able, almost without further explanation, to state just how extremely unlikely this notion is. There are three very powerful reasons for this: (1) Order-of-magnitude problems, (2) "Seed energy" realities, and (3) the "all electricity" problem.

Starting with the last of these, the "all electricity" problem, let us take another look at Table 2, and specifically at items 4. to 10. These, again, are the non-GINF's; that is, the things which are <u>not</u> fossil fuels and which are at least for the most part, renewable. These have in common (exception is biofuels which is tiny) the fact that they are all technologies or substances which are geared to produce energy by way of producing electricity. This is more than a second level problem because it is generally accepted that it takes about 3 Btu's of primary energy to produce 1 Btu of electrical energy.

In the current reality of the years 2014-2016, for example, the world's energy use is split between about 55 percent primary and about 45% electrical, a split which has stayed roughly constant for the last three decades. In the eventual non-fossil world, this split will be approximately zero percent primary and 100 percent electrical. This, then, would change the quads game considerably because 3 times 0.55 (55%) is 1.65, and 1.65 + 0.45 (45%) is 2.10, implying that, for example, the 532 quads in Table 2 would now become at least two times this number, well over 1,000 quads.

The other two problems listed three paragraphs back are "Order-of magnitude-problems" and "seed energy realities" which can be handled together at the same time. In order to do this even better, however, we should first introduce the final table of this piece, Table 3, which also brings back into this discussion the final item of Table 1, item C., Human Population.

We are all well aware of our current population, 7.3 billion, and we are also well aware of the fact that demographers and others have been talking about numbers such as 9 and 11 billion as reasonable projections for world human population in years such as 2040 and 2095, respectively. In Table 3, we have these three population numbers repeated along with the corresponding energy needs for such populations using the current number of quads of energy per billion people (about 73) and also a level of 10% less energy per billion and also 20 percent less.

**Table 3**

Worldwide quads of energy necessary under various scenarios of human population and quads per billion of population.

| **World Human Population** | **Quads using current 73 quads per billion** | **Quads using 10% less than current 73** | **Quads using 20% less than current 73** |
|---|---|---|---|
| Current $7.3 \times 10^9$ | 532 | – – | – – |
| $9.0 \times 10^9$ | 656 | 590 | 525 |
| $11.0 \times 10^9$ | 802 | 722 | 642 |

As we can see, the smallest number in the table is 525 quads per year and the largest is 802. Also, these numbers are extrapolations from the current 532 figure, a number which reflects a mix of about 55% energy as purely primary and only about 45% as electricity. As mentioned earlier, the reality of the world to come is that of "all electrical", such that the numbers in Table 3 are really understated, probably by a factor of at least 2.0. As an example, therefore, the small number of 525 would therefore be well over a thousand.

Can we get to 500 or 1000 or 1500 quads per year of energy without the GINF's? Or, putting it a different way, are the GINF's really not GINF's? Are crude, gas, and coal indeed fungible? Can they be replaced to a truly meaningful extent? This writer firmly believes that the answer to this is no, and it is now time to prove this point or, if an absolute proof is impossible, at the very least point out key facts that bring us, at a minimum, close to a proof.

Going back to Table 2, let us consider items 4. through 10. in a realistic way.

Number 4., nuclear fission will increase, but probably quite modestly, perhaps from current roughly 30 quads per year to perhaps 50. I believe that the increase will be this modest because of (1) the Fukushima disaster of 2011, (2) the widespread fear of this technology even before 2011, and (3) the fact that high-quality fissionable material is, indeed, also a finite resource.

Number 5., hydroelectric, will also increase, but even a doubling of the number would change the picture very little, and going beyond a doubling is unlikely due to the fact that the damming of rivers, and hybrids of this concept, are already close to a practical saturation point speaking at least on a worldwide basis.

Numbers 6. and 7., Biomass and Biofuels, could increase by perhaps 100%, but even this would buy us only about 50 quads more in a ballgame in which we need to make up for the eventual loss of 430 quads (crude + gas + coal) or considerably more than this number taking account of the arguments regarding "primary energy" versus "all electrical" as discussed above.

In the case of number 8., geothermal, we are at the very least looking at a large order-of-magnitude problem. For example, if this area could grow to fully 10 times its current size, this would provide only about 10 times 2 = 20 quads additional, again in a ballgame in which numbers like 20 are not what are needed but rather numbers like 200 are, and indeed several numbers of order 200. Also, geothermal is not some kind of new just-discovered-yesterday marvel such that giant increases can be expected. Some of the best-known geothermal installations in the world, such as Larderello in Italy, have been around for more than a century.

This brings us to the two technology areas of wind and solar. As we all know, these two areas are currently very topical and both also share the reality that they have both had significant growth trajectories in recent decades, albeit with a certain amount of stops and starts. They both also share the fact that their numbers in Table 2 are not yet very large, but they have many enthusiastic backers and it is likely that these numbers could continue to grow dramatically in the next few more decades.

Indeed I would go further and say that they will grow dramatically in the next few decades. This is because, as we know, governments have put in place mandates which require that by a certain stated date certain percentages must be met which are either percentage of electricity that is from renewable sources of energy or specific percentage decreases in emissions from a stated existing emissions baseline. These dates, such as the year 2025, 2030 and so on, will almost automatically drive growth of wind and solar.

And I say wind and solar not because I believe that they are necessarily the best technologies with which to deal with these mandates, but much more so because they are possibly the only ones. The affirmation of this latter statement only requires another look back at Table 2. Of the various line items there, wind and solar arguably have the fewest negative aspects currently attached to them. With this reality at their backs, their continued build-out is essentially assured.

A definitive proof that wind and solar can or cannot deliver 500 or 1000 quads of energy per year is nearly impossible without the investment of many hundreds of person-hours and tens of thousands of words of explanation. And: any such "proof", here in the years 2015 – 2016, after no matter how much care and refinement and completeness, would be accepted by nearly no one without an absolute proof of efficacy or non-efficacy which, sadly, is generally only seen after a very lengthy and very costly true physical build-out. An example of this is the failed ethanol concept.

But a very strong partial answer is available to us, and this is a fact about which almost no one appears to be fully aware: When the GINF's are gone, the winds and solars of the world will have to stand on their own in a decade-after-decade sense with no "seed energy" from which to build and maintain themselves. That is, the energy from these new sources will have to be so enormous in what they alone produce that they are not only able to generate the 500 or 1000 quads net per year but also the energy necessary to "reproduce themselves".

This is not likely and is not happening today: that is, the engineering, fabrication, delivery, installation, and maintenance of the current solar and wind power fleets have been done, indeed, "on the backs of" the energy sources, the "GINF's", which we, in the future, are no longer going to have.

But just to make certain that we are doubly underlining this point, let us look back again to Table 2, the "graphic" table. In it, wind plus solar sum to 8 quads. In the "world to come", they would have to sum to an order-of-magnitude of very roughly 1000 quads, 125 times as much, and with this being done autonomously. This is so extremely unlikely that this writer is obliged to look elsewhere for resolution.

This, then, brings us to the final item in Table 1, item C., Human Population, and also brings us to the final conclusions of this opinion piece.

The world could gamble away many decades in the hope that wind and/or solar and/or a basket of various technologies might be able to "fix the GINF Ratio" and also the climate change dilemma. Since this is nearly 100% unlikely, the world has no real choice, then, except to address the denominator of the GINF ratio instead of the giant emphasis on the numerator. The latter is most definitely the recommendation of this writer because, in my opinion, the carrying capacity of this planet is not 11 billion humans nor 9 billion nor even the current 7.3 billion. Many pieces have been written, it is true, speculating numbers as high as these or even higher, but many other pieces speculating much smaller numbers. My own belief is that the carrying capacity is between 2.5 and 4.0 billion depending extremely heavily upon the level of moderation of resource impact per person.

In spite of the almost child-like simplicity of the GINF Ratio, it is a powerful metric. In my view it brings us back to reality and forces us to stop doing what I believe we have been doing for the last several decades, namely observing a kind of "gag rule" against the discussion of world human population and the need not only to reduce it but to reduce it significantly and maintain it at this significantly reduced level.

Some readers may very well point out that this is already well under way, given the fact that several countries on earth already have their populations declining at a rate which is at least somewhat significant and several others are projected to move into this column in the next few decades. And these are indeed facts, at least at the moment of this writing.

I must introduce, however, a concept which I feel could cause a dangerous reversal of these trends. I believe that there could occur a phenomenon which I will call "subliminal desire for organic growth", "organic growth" in this case referring to how the term is used in the context of business enterprises. There is a potential danger that the governments of countries and/or businesses within these countries could look at the decreasing population numbers in their nations (or in their markets, speaking of multiple nations) and see that they are not comfortable with a shrinking importance. This could cause a reversal of population moderation in such countries and, conceivably, a reversal in still <u>other</u> countries who view this as either a "market threat" or an excuse to decrease moderation efforts themselves.

But whether or not these latter speculations do or do not cause upsets in a path back to the carrying capacity of this planet, one thing is most certainly true: We are going to be at numbers far above the carrying capacity for a very long time, and the longer this time, clearly, the worse will be the final outcomes.

To borrow a term from the "Corporate America" of the late 20th century, companies, states, provinces and nations are going to have to "right-size themselves", are going to have to be comfortable with less people, less organic growth based on population growth and, in short, with a whole new reality which will have to be both very different and very permanent.

The above, then, become the conclusions of this paper, and the conclusions of this writer with regard to the three great questions in Table 1: (A) that climate change should not be dealt with by concepts such as "Stranded Assets" because it creates huge new problems such as "Stranded Asset Users", (B) that energy finiteness cannot be solved by renewables because of a long list of technical and order-of-magnitude problems together with the fact that current world population and current number of quads per year per billion of population make this intractable in any event, and (C) that the only realistic answer for all three items in Table 1 is a permanent reduction in world human population and quads of energy per billion of population, with heavy emphasis on what is written in the five brief paragraphs immediately preceding this one.

And let us by no means take any comfort in the fact that we may have enough energy to serve our needs until the year 2095 or 2095 plus one more increment of 75 or 80 years. These time-frames are essentially <u>tomorrow</u> and, as such, must be understood today and then acted upon based on that understanding, also starting today.

And let us also by no means take any comfort in what some might see as great new hopes or great new game-changers. The technologies surrounding tight oil, fracking, and shale gas, for example, are <u>not</u> ever going to prove to be game-changers. They will have been additive in a Btu sense, definitely, but they will end up changing the huge order-of-magnitude picture extremely little. And, as a related point, the large decrease in crude oil prices beginning in the autumn of 2014 does <u>not</u> represent a game-changer , either; it represents (or represent<u>ed!</u>) a simple market reality

of everyone getting into production immediately after a transient high-point in the price of this commodity. Another area which will not be a game-changer is nuclear fusion; anything requiring reaction temperatures in the millions of degrees centigrade has a likelihood, here on earth, so low that it is safe to say that it is not going to be a player.

And as I end this opinion piece, let me reiterate what I wrote a few paragraphs back, paraphrasing slightly: The world could gamble away many decades in the hope that it can fix the GINF Ratio and climate change by way of unlikely attempts against the numerator of the GINF Ratio, or it can take the vastly more likely path of various realistic approaches regarding the denominator. I can confidently state that in two decades there will be very few observers who will challenge this statement, and, that in three decades, there will be none.